IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

June 12 to 15, 2011

San Diego, CA

Wafer-Scale Contactor Development and Deployment

multitest

A DOVER COMPANY

Jim Brandes

Contactor Products

Outline

- Probe Development
- Emergence of Wafer-Level Test
- Engagement to Develop WL Contactors
- Field Deployment of WLCSP Contactors
- Challenges and Setbacks
- Separating Reality from Perception
- Progress and Solutions
- Lessons Learned and Path Forward
- Summary

Probe Development

- **Multitest and ECT have been making spring probes for over thirty years**
  - Probes have evolved over time to meet needs of final test
  - High Electrical Performance, Long Life
  - Highest-performance probes have always been reserved for test contactors

CSP

Bantam

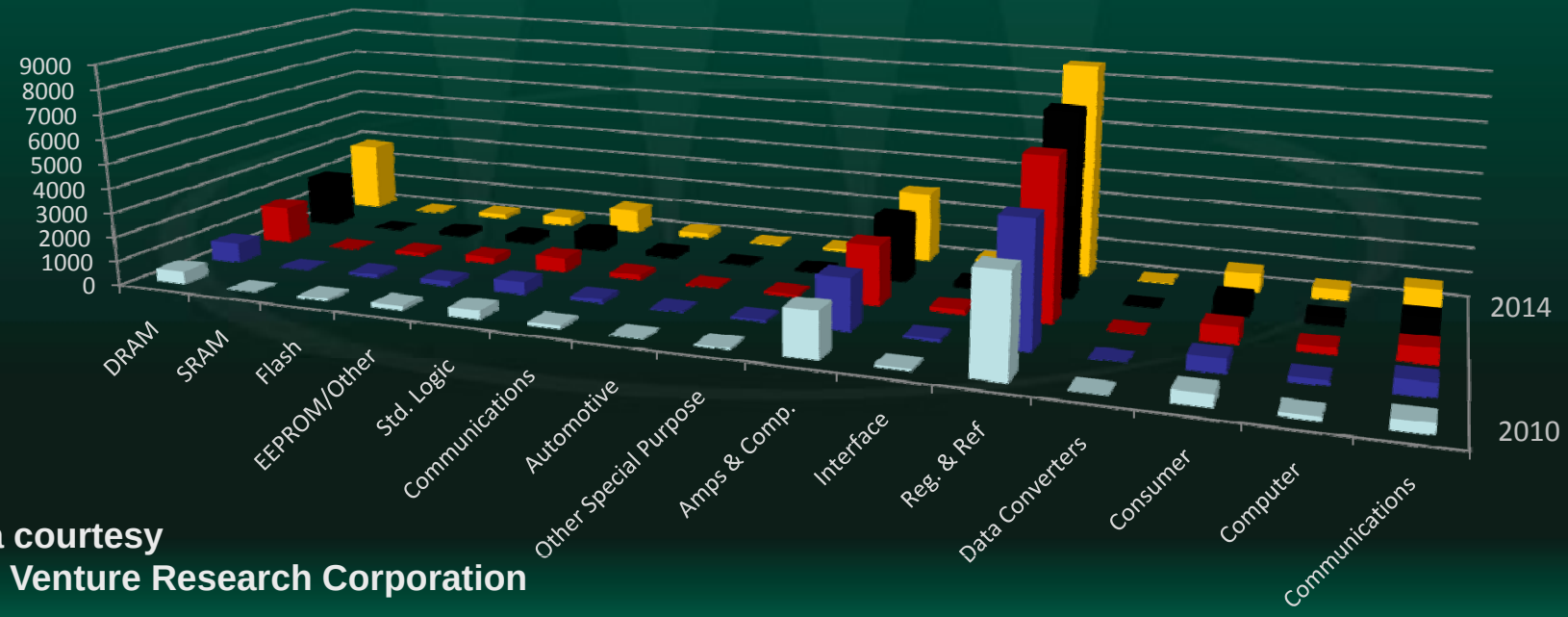
Gemini

Probe Development

- **2009 Recession drove development of lower-cost probe**
  - Maintaining high performance a challenge
  - Required development of new manufacturing technique
- **Result: Mercury probe**
  - Electrical performance nearly that of Bantam
  - Longer life than Bantam
  - Half the price of Bantam

Emergence of Wafer-Level Test

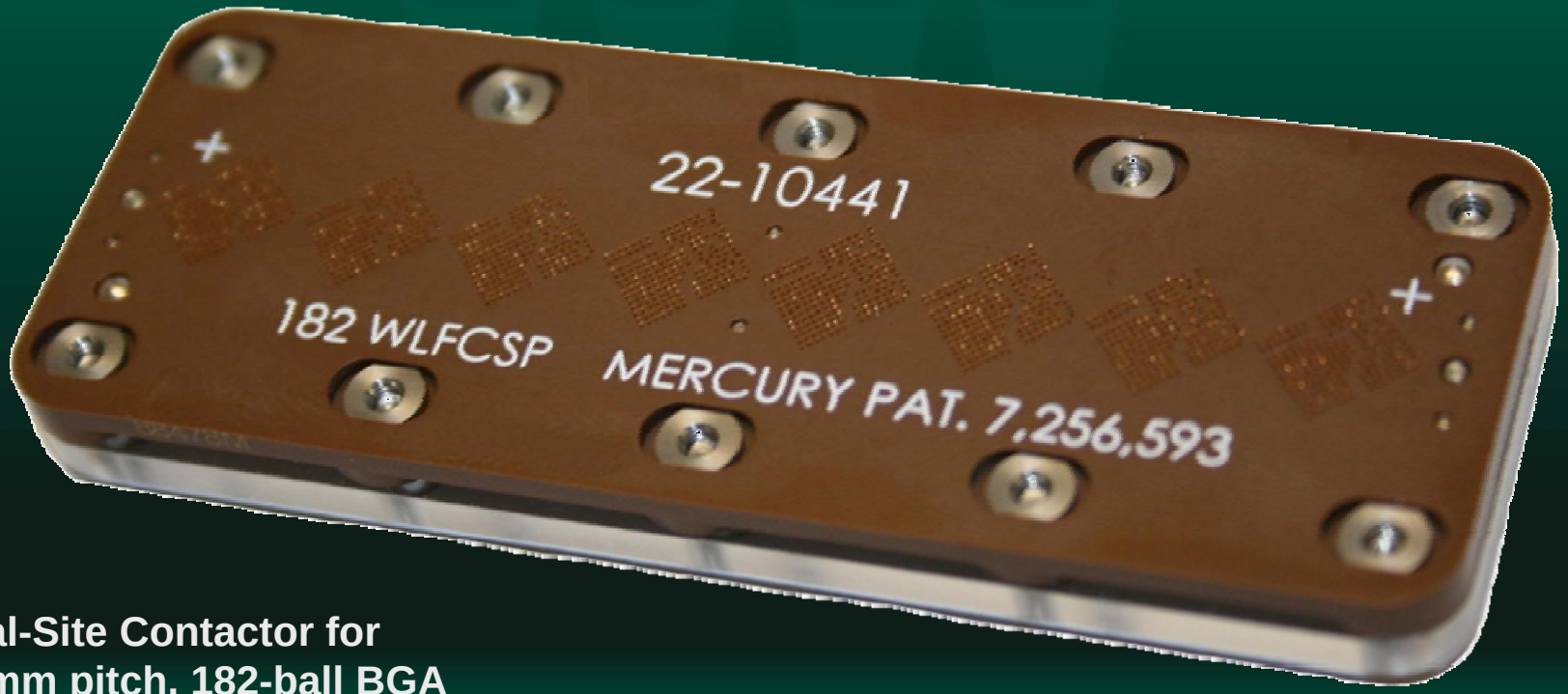
- **Simultaneous emerging trend**
  - Wafer-level devices are a small, but rapidly-growing device segment
  - Driven by the need for smaller devices for mobile applications
  - Final test at the wafer level is one appealing facet of WLCSP



Data courtesy
New Venture Research Corporation

Request from Fabless Manufacturer

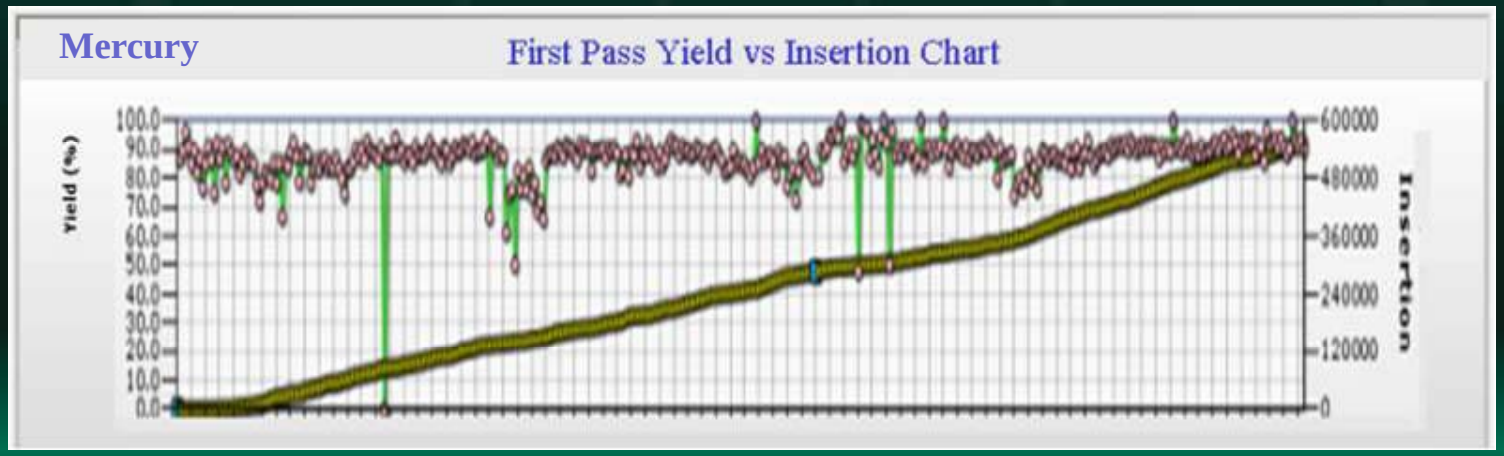
- Had purchased many contactors for singulated devices
- Requested quote for large, multi-site WLCSP contactor



Octal-Site Contactor for
0.4 mm pitch, 182-ball BGA

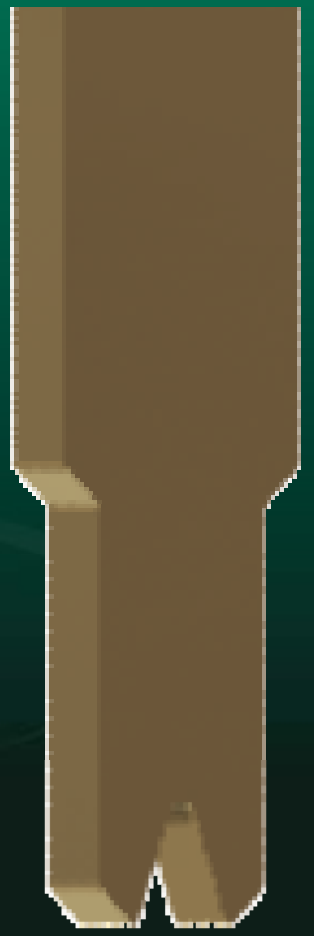
Manufacture / Initial Check-Out

- **The design and fabrication presented no challenges**
  - Multitest experienced with wafer-level contactors
  - Designs are simple
- **Mercury 0.4 mm pitch probe chosen**
  - Met the electrical requirements of the application
  - User had experience / comfort with Mercury technology
- **User did initial check-out in the United States**
  - Initial check-out using Singulated devices – hand test
  - Verified electrical performance of entire interface



Manufacture / Initial Check-Out

- **Check-out continued using a wafer prober**
  - There were some challenges with alignment
    - Spring probe tip positions are not held as tightly as traditional probes
    - Wafer prober had difficulty finding probe tips
  - No issue with execution after alignment
    - WL Targets (solder balls or bumps) are larger than die pads
    - There is a degree of self-alignment between solder ball and probe tip
- **Initial test results were very good**
  - First pass yield better than previous solution
  - Final yield also improved



Mercury Probe Tip

Transition to Subcons

- **High-Volume test occurring in Taiwan and Singapore**
- **Alignment was initially an issue**
  - Required manual intervention on first wafer
  - Took more time than desirable
  - Design changes in contactor improved positional stability of probes
  - Improved algorithms were employed
- **Improved yields of 2% – 6% seen immediately**
  - Incentive to work through issues
  - Not all issues are real, some are perception
- **Over fifty contactors running high-volume production**
- **> 96% First-pass yield (average)**
- **> 98% Final yield (average)**

Separating Fact from Perception

- **Some issues at subcons are real problems**
- **Some perceived issues are due to the difference between traditional probe cards for die and spring-pin contactors**
  - Planarity
  - Probe X/Y positional accuracy
  - Contactor body material (plastic) dimensional stability
  - Probe life

Separating Fact from Perception

Perception: Spring Probe Contactors are not Planar Enough

- **Die pads are extremely coplanar**
  - Traditional probe cards have very little compliance (overdrive)
  - Consequently probe cards are made with very consistent Z heights
- **Solder balls on wafer-level devices are less coplanar**
  - Spring probes have much more compliance
  - Consequently spring probes do not require as much Z consistency
- **Probe preload causes deformation (sag) in center of array**
  - Array flattens out as wafer is engaged and preload is removed
  - Coplanarity deviation is disconcerting to user
  - Resolution: Multitest is working to reduce the deformation with new body materials

Reality: Planarity Adequate, but Improvements Being Made

Separating Fact from Perception

Perception: Probes' X/ Y Positions are not Accurate Enough

- **Die targets (metal pads) are very small**
- **Die targets (metal pads) are arranged at tight pitches**
- **Traditional probe technologies must have matching accuracy**
- **Wafer-Level device targets (solder balls) are relatively large by comparison**
- **Spring probe tips are somewhat self-aligning**
  - Small amount of X/Y mobility
  - Crown tips *cradle* solder ball

Reality: Probe Tip Positions are Accurate Enough for WL Test

Separating Fact from Perception

Perception: Probes' X/ Y Positions are not Accurate Enough

- **Initial positional accuracy challenge was alignment**
  - Probers have a target window within which to look for probe tips
  - Window is scaled to the positional accuracy of traditional probe cards
  - Opening window to see spring probe tips is a concern to operators
- **Designs have evolved to improve positional consistency**
- **Multitest is working with the prober manufacturers and subcontractors to develop improved alignment algorithms**

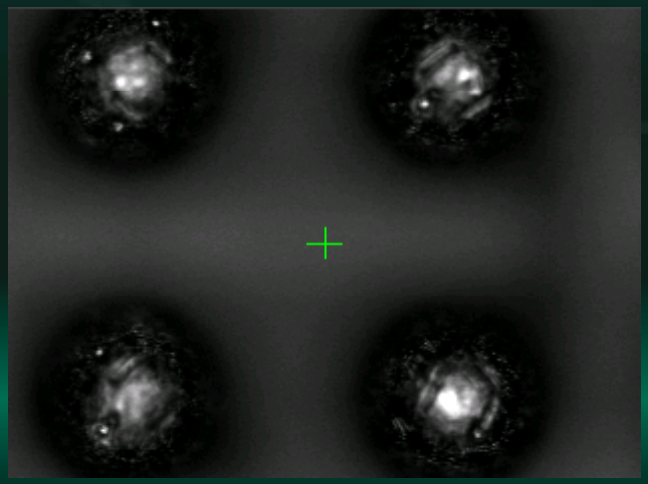
Reality: The Contacts *Are* Being Aligned

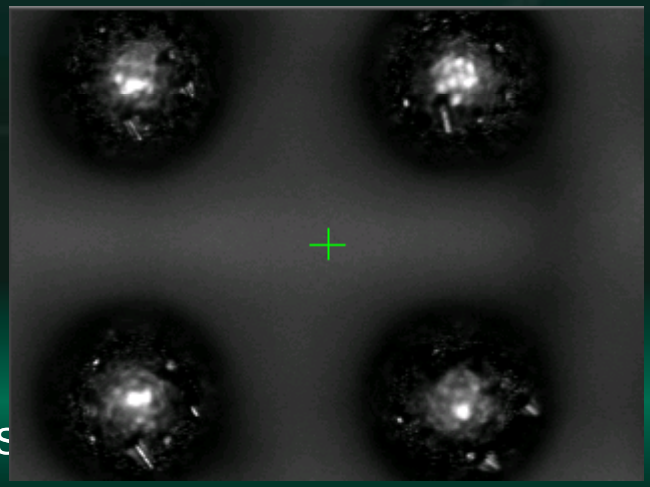
Separating Fact from Perception

Perception: Contactor Dimensionally Unstable

- **Contactor growth due to hygroscopy – a real issue**
  - All plastics absorb moisture, causing them to grow
  - The standard plastic used in these contactors grows over time
- **Problem appears after several months**
  - "Best-fit" alignment algorithms initially work well
    - Excellent probe marks over entire array
  - Over time, the contactor grows
    - Excellent probe marks in middle of array, ends moving away from center
    - Eventually can cause ball shear on solder balls farthest from center

Site 4





Site 7

Separating Fact from Perception

Perception: Contactor Dimensionally Unstable

- **Contactor growth due to hygroscopy – a real issue (continued)**
- **Ironically, this plastic was chosen over the previous plastic used because it has about half the hygroscopic growth**
  - The 0.3% growth has been very acceptable for singulated devices
  - It is proving to be too much for large, multi-site, fine-pitch probe arrays
- **Plastic returns to original dimensions when moisture removed**

Reality: Contactor is growing over time

Resolution: For large arrays, Contactors are Designed using a Lower-Hygroscopy Material

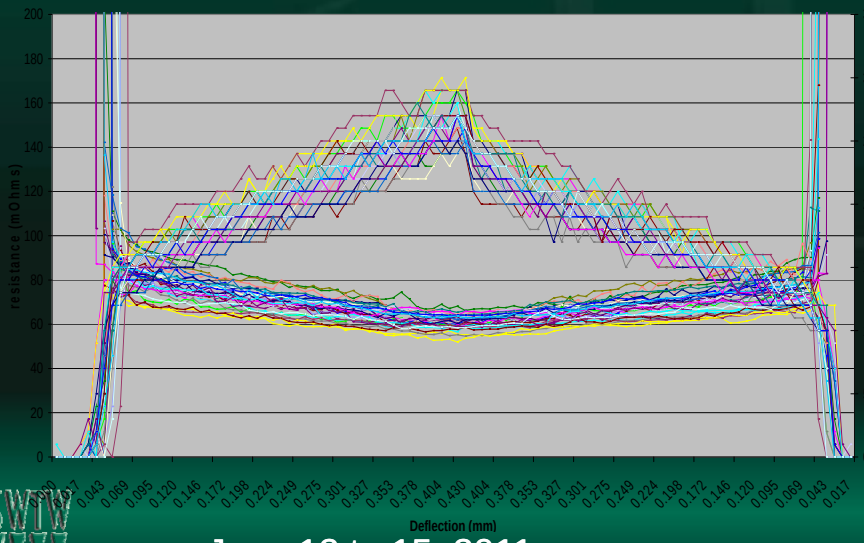
  - Multitest continues to investigate alternate materials

Separating Fact from Perception

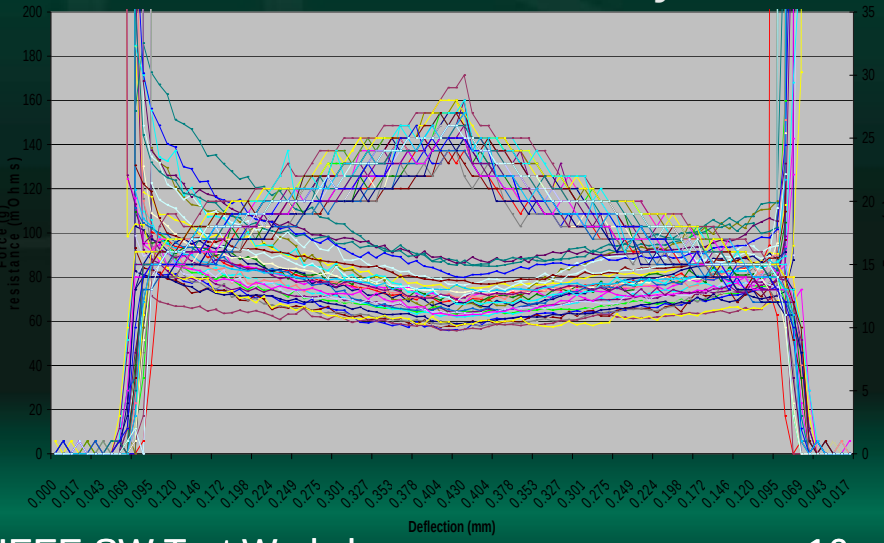
Perception: Spring Probes are Short-Lived

- **Probes rated to have life of "More than 500 k insertions"**
  - Specification based on customer feedback
  - Based on high-volume use, testing singulated devices in handlers
- **Probe life much greater when used for wafer-level test**
- **The probes are achieving >1 M insertions in WL applications**

FReD Plot of New Probes



Same Probes after 1 M cycles



Separating Fact from Perception

Perception: Spring Probes are Short-Lived

- **Currently ranging from 1.5 M to > 4 M and still going!**
- **Why does wafer-level test allow longer life than package test?**
  - Ideal presentation
    - Planar
    - Controlled overdrive
    - Optical alignment
  - Clean environment
  - In-Situ cleaning
    - Keeps probes in top operating condition

SEM Photo of probe tip after being plunged 10 k times in elastomeric cleaning media

Reality: Spring Probes Provide Excellent Operating Life

Lessons Learned

- **Prober users speak a different language than handler users**
  - Probe card instead of contactor (or socket)
  - Overdrive instead of compliance
  - Dimensions in microns, rather than mm
  - Unheard-of precision
- **Users expect positional accuracies in the microns**
- **Alignment algorithms are customized to each different probe technology**
- **New body materials, and perhaps machining techniques are required**
- **0.4 mm pitch is only the beginning . . .**

Path Forward

New Body Materials

- **Performance considerations**
  - Extreme rigidity to maintain flatness
  - Not too brittle
  - Low or no hygroscopy
  - Machinable
- **Commercial considerations**
  - Cost
  - Lead time

Path Forward

Finer-Pitch Probes

- **0.3 mm Kelvin**
- **0.3 mm non-Kelvin**
- **Considerations**
  - Electrical performance
    - High conductivity
    - Low inductance
    - High bandwidth
  - Mechanical Performance
    - High compliance
    - Long life

Summary

- **Wafer-level test is an important, fast-growing segment**
- **Wafer-level test requires higher electrical performance than wafer probe**
- **Spring probes can provide the required performance**
- **Flat-technology spring probes are superior**
  - Electrical performance
  - Cost of ownership
    - Low initial price
    - High yields
    - Long life
    - Field-servicable
  - Proven track record in high-volume production
- **Some adaptation required for the WL environment**
  - New materials, possibly machining techniques
- **Need finer pitches going forward – a real challenge**

Thank You

Questions?